PROTOCOL ASSISTED SWITCHED DIVERSITY OF ANTENNAS

Field of the Invention:

[0001] This invention relates to improving the reception of digital radio signals with reduced-complexity radio receivers, such as those which may be used with handheld multimedia communication devices in wireless LAN applications. It particularly relates to radio receivers with multiple antennas. In particular, the present invention uses a protocol assisted switched diversity antenna system.

Background of the Invention:

[0002] Wireless LANs (Local Area networks) differ from wired LANs in that various radio transmission channels may interfere with one another. Indeed signal propagation is further subject to many variations in signal strength due to such factors as multipathing a result of the various propagation paths a wireless signal may experience and other factors that interfere with a clean signal. Diversity is one means of dealing with these various effects.

[0003] Antenna spatial diversity is one of the most powerful techniques for improvement of radio channel quality. The technique assumes that radio signals arrive at antennas displaced in space via substantially different propagation paths when a multipath (Rayleigh) propagation environment is present. Thus, the signals arriving at each antenna are substantially decorrelated (provided large enough antenna spacing is used), and impairments which may affect each of them due to multipath fading are mostly non-overlapping in time and frequency. Using the two signals in combination, with an appropriate combining technique based on a quality metric (*e.g.* received signal strength), can allow better communication quality to be sustained.

[0004] In order to capitalize on the full value of antenna diversity, it is conventional to implement duplicate receivers for each antenna path. Although this "combinational" diversity approach is very effective, it can be costly and difficult to implement in a low power

environment. A simpler approach, using a smaller number of receivers than the number of antennas is called "switched diversity". In these implementations, the receiver uses one of the antennas to recover the desired signal while monitoring the quality metric. If the quality metric falls below an acceptable level, an RF switch is actuated to connect the receiver instantaneously to a different antenna.

[0005] Usually switched diversity usage is relegated to analog transmission systems (*e.g.* analog cellular) or digital systems, which can accommodate retransmission of unacknowledged or negatively acknowledged messages. For systems in which the radio channel remains stationary for an acceptable interval, switched diversity may be applied using a large number of antennas. Conventional switched diversity systems, however, do not cooperate with MAC protocols since the switching of the antenna is autonomous at the receiver.

[0006] Wireless LANs are now being contemplated for delivery of time-bound multimedia communications in addition to their current use for non-time-bound data. Protocols have been developed for providing scheduled, non-conflicting time intervals for transmission of multimedia packets whose latency requirements cannot accommodate conventional retransmissions for error correction. Because delays caused by ack/nak-directed retransmission cannot be tolerated, one must seek other means to reduce error rate. Forward error correction coding is usually used for such purposes, but its use may incur large coding overheads in the case of multipath propagation environments where a significant number of symbols may be eliminated by a fade at a single antenna.

[0007] Although combinational diversity is an attractive means of reducing error rate in multipath environments, wireless LAN clients frequently require low dissipation and small (PC-MCIA) form factors, and are less able to support the complexity and cost of multiple receivers. Eventually, VLSI techniques will succeed in meeting the size, cost, and dissipation requirements for these clients. However, it would be advantageous to have a means by which the switched-diversity architectures in use for today's wireless LAN receivers could be utilized to provide the

necessary improved BER performance in association with software-based protocol and coding techniques.

Summary of the Invention:

[0008] An exemplary diversity system involves use of a novel fusion of switched diversity with protocol-based transmission redundancy and error-correction coding to improve to improve the performance of radio receivers. A specific embodiment disclosed herein uses a single receiver which may be connected to more than one antenna via an RF switch. In contrast to conventional switched-diversity operation, the switch is controlled, not by signal strength or other metric, but rather incremented by the sequence number of a series of scheduled packet bursts which are prescribed by a QoS protocol. The message itself is recovered from the series of packet transmissions, each displaced in time. Each transmission may be coded in such a way as to provide a combination of error-correction coding and user data, providing a trade-off opportunity between radio resource use and error rate. An example of a coding scheme which may be utilized is space-time codes.

[0009] In one particular embodiment a receiver of a base station having two decorrelated antennas is enabled to operate with a fusion of switched diversity reception and protocol based redundancy using time spaced transmission bursts, each containing the same message, to improve the performance of radio receivers (i.e., including mobile receivers) in a WLAN. The protocol works with the antenna switching process to provide the best signal reception.

[0010] In another embodiment space-time codes are used to spread the message information over the two transmitted bursts separated in time within a PCF control frame such as defined in the WLAN 802.11 standard. This advantageously allows reduction of radio resource use as compared with the above redundant transmissions. The robustness of the operation is maintained.

[0011] These embodiments may include a capability of notifying a transmitting end from a receiving end of the transmission that a client receiver is capable of protocol assisted switched diversity operations, including the number of antennas and receivers available for reception.

[0012] In another aspect of the invention, where enough bursts have been received successfully to reconstruct the transmitted message (via check sum or other error detection technique), an option is given a receiving end of the system to acknowledge correct receipt of the message. A transmitting end to may use this acknowledgement to cause the transmitting part of the system to cease sending diversity bursts. This permits a significant conservation of system radio resources.

Description of the Drawing:

[0013] FIG. 1 is a schematic of an exemplary receiver using two antennas to achieve spatial diversity; and

[0014] FIG. 2 is a graph of control protocol frames used in an exemplary transmission media.

Detailed Description:

[0015] In an examplary two-antenna, one-receiver embodiment as shown in Figure 1, receiver (100) is connected to antennas (101 and 102) by an RF switch (103). The receiver consists of a conventional analog RF processing (104), signal strength measurement (105) and digital demodulation (106) facilities. The digital output of the receiver, consisting of message symbols and associated signal strength values, is connected to a buffer memory arrays (107 and 108). Control of RF switch 103 is accomplished with the aid of microcomputer (109) which executes a stored program implementing the MAC protocol. Based on the state of the protocol, the RF switch control will be operated in the conventional mode (switching based on an RF

signal strength quality metric as described above), or in the multiple burst mode (where it is switched to ensure that a particular burst is received by a particular antenna.

[0016] For the purposes of this example, the base station will be assumed to have at least combinational diversity reception, and may also support transmit diversity. In operation, the method works as follows: Operating in the conventional switched-diversity mode, the client receiver has acquired the RF channel and has selected an antenna which is delivering acceptable signal strength. By receiving the channel for a period of time, the receiver has allowed the MAC microprocessor to synchronize with the base station transmissions and to cooperate according to protocol rules for channel access. The MAC communicates to the base station that its hardware configuration supports switched-diversity QoS improvement as part of its session-access preamble, during which it requests a specific stream QoS type. Ordinarily, the switched-diversity QoS option would be engaged only for high-priority traffic in a priority-based scheduling system, or for the traffic requiring the highest end-to-end QoS performance in a parameter-based system. The balance of the example will assume that the "parameterized-QoS" mode is used (see Figure 2).

[0017] The QoS mode illustrated in Figure 2 uses a protocol set of a proposed 802.11e standard. In this protocol set, a station (STA/client) communicating with an access port (AP) may only use the wireless transmission medium during specified periods of time. These specified periods of time include Contention Free Periods (CFPs), Controlled Contention intervals (CCI) and Resource Reservation (RR) frames and Contention Control (CC) frames. A controller grants the transmission medium for use by RR frames by transmitting a CC frame. Only RR frames are transmitted during a time period specified by the CCI frame. The RR frames define the needed Bandwidth of the designated QoS. The CC frames designate parameter for the CCI. Further details of this procedure are contained in the 802.11 proposal of the IEEE.

[0018] When the base station determines that downlink (to the client) traffic has arrived from the network, it schedules a series of burst transmissions (in this example, two). The base station initiates message transmission by issuing a polling request, followed by the first packet

burst. The first burst, containing the message, will be received exclusively on the antenna which has been in use (the RF switch remains set for the duration of the burst). While the burst is being received, the receiver's output (soft symbols and signal strength values) is stored sequentially in buffer 107. At the conclusion of the base station's transmission, the client transmits a polling response, followed by any uplink (to the base station) traffic it may have to send. The microprocessor, which has been adhering the protocol, immediately causes the RF switch to connect the alternate antenna to the receiver, in preparation for reception of the second burst, containing the same message. At some later moment in the current superframe or a subsequent superframe, the base station transmits a second polling request and the second packet burst. This burst is received exclusively using the second antenna; the receiver output is similarly stored sequentially in buffer 108.

[0019] Following receipt of the second burst, the microcomputer extracts the first symbol of the first burst from buffer 107 with its corresponding signal strength value. Likewise, it extracts the first symbol of the second burst from buffer 108, with its corresponding signal strength value. Using a combination of symbol decoding, error correction decoding, and combining based on the signal strength metric, the desired message is extracted. Techniques such as Maximal Ratio Combining (MRC), well known to those skilled in the art, could be used for this purpose.

[0020] Since the method uses implicit time-displaced redundancy in cooperation with antenna diversity, the quality of the recovered message is comparable to conventional combinational diversity if the channel is stationary during the interval which includes both bursts and the bursts contain exactly the same information. If the channel is not stationary over this interval, the method produces a form of space-time spreading, which may provide improvement over combinational diversity methods.

[0021] Using identical (duplicated) transmission in the bursts uses twice the radio resource than would be required with a combinational diversity system. For time-bound (fixed duration) material which uses relatively short packets (*e.g.* digital voice), this increase in

resource usage would undoubtedly be an acceptable trade-off for increased quality and hardware simplicity. For high throughput (large packet) traffic, total redundancy of packets may constitute unacceptable overhead. Accordingly, by use of appropriate coding techniques (*e.g.* space-time codes) it is possible to trade off quality improvement for radio resource usage by partially or completely spreading the message across the bursts. Such a strategy allows flexibility between BER improvement and channel occupancy. Space-time codes may be used for improving performance in a wireless environment and when combined with protocol switched diversity significantly improves transmission efficiency over that of the protocol switched diversity alone.

[0022] Additions to the invention may include adding an ability of the system to communicate from a terminating end to a transmitter to specify the receiver capability to perform protocol assisted diversity operation and include the number of antennas and radio receivers that the terminating end has.

[0023] In another arrangement, the receiving end may notify a transmitting end promptly if a message is successfully received, allowing reconstructing of the transmitted message, before a subsequent burst is received. This allows action to cease further transmission of bursts related to this particular message thereby resulting in a conserving of radio resources in the system.

[0024] Those skilled in the art may devise many variations of these schemes without departing from the spirit and scope of the invention. A hybrid architecture consisting of switched-diversity and combinational diversity elements may be used (*e.g.* four antennas, a 4x4 switch matrix, and two receivers) to provide significantly improved performance over conventional two-branch combinational diversity.